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SHORT COMMUNICATION

Optimum Location and System Engineering of High Power, High Frequency Transmitter-Receiver in Combat Vehicles

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ABSTRACT

This paper discusses the procedure adapted after carrying out several iterations for selecting an ideal location to introduce a high power high frequency (HF) transmitter-receiver in a tactical combat vehicle from electromagnetic compatibility view. This radio set contributes for very high field strength to neighbouring electronic devices and other very high frequency (VHF) Tx-Rx situated in the same vehicular platform. An integrated approach was followed in deciding the optimum solution to locate the HF radio set. Leakage from HF radio set is to be minimised within the vehicle to reduce the field coupling level to neighbouring equipment. Radiation from HF antenna was maximised by careful installation of antenna, outside the vehicle environment to ensure optimum radiation of intended signal. Voltage standing wave ratio (VSWR) measurement was carried out to verify this. Four different locations experimented have been reported in this paper. The vehicle penetration loss (VPL) can reveal the amount of leakage from external field generated by antennas to field inside the turret. The HF, being a congested operating spectrum, due care was taken in electromagnetic interference control of HF-VHF radios and other tank electronic subsystems. High RF power of HF transmitter and very high sensitivity of HF receiver could affect systems either way. Hence, electromagnetic compatibility (EMC) measures and optimum location of HF radio set are important from MIL-STD461 C, MIL6051-D/MIL-STD464A point of view.

Keywords: Spectral congestion, electromagnetic interference, EMI, VSWR, vehicle penetration loss, voltage standing wave ratio, VPL

1. INTRODUCTION

Hitherto tracked combat vehicles in armoured fleet were using only a 50 W of radio frequency (RF) power, high frequency(HF) radio set for long-distance ground communication link. Of late, with the development of solid state frequency hopping radios, high power radios have come into use, particularly for enhanced voice communication range requirement and also for data transmission capability. These requirements have compelled the radio set designers to think of high power HF radio sets, but this leads to several electromagnetic interference (EMI) issues, if the due care is not taken during system integration in the vehicular platform. Typical range[1] achievable with various RF power levels in a HF radio set is depicted in Fig. 1 as an approximate estimate. This is basically derived from the thumb rule equation given by:

$$R \approx \sqrt[3]{P} \qquad (1)$$

where, R is the range (km) and P is the effective RF power radiated (watt).

An increase in transmit power extends the range only insignificantly. To achieve double the range, one has to increase the transmit power by eight times. For the present case of 100 W, at least 35 km range is expected at highest frequency of 30 MHz. But at lower frequencies, the maximum range of 50 km can be expected. Whenever there is reduction in range, it could be due to severe propagation loss/fading or due to interfering signals or both in the Tx-Rx system[2].

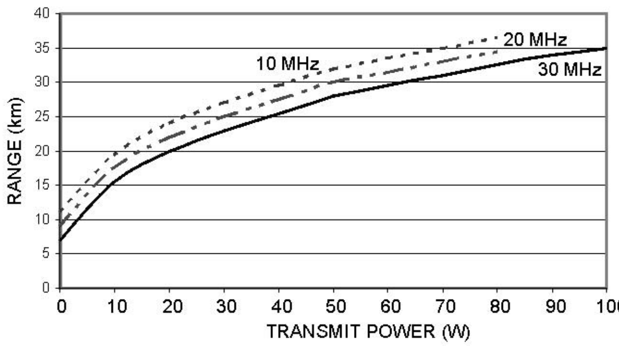

Figure 1. Range of radio signal as a function of transmit power with frequency as parameter.

As far as data transmission is concerned, range achievable largely depends on the bandwidth of channel as is evident from Fig. 2.

The required bandwidth is proportional to the data rate.

$$R \propto \frac{1}{\sqrt[c]{\beta_{HF}}} \qquad (2)$$

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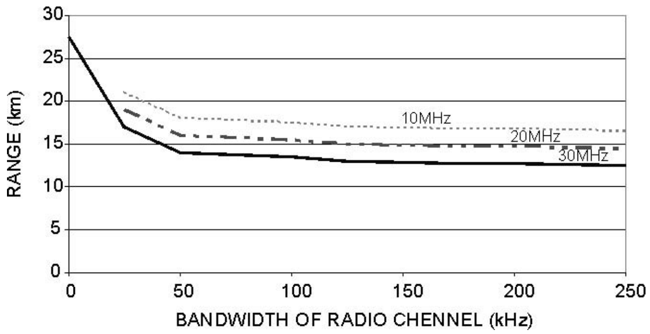


Figure 2. Range as a function of the bandwidth of radio channel.

where, R is the range (km), $â_{HF}$ is the required bandwidth (kHz) or requested data rate. However the range decreases with increase in bandwidth/rise in data rate. If effective radiated power is reduced due to mis-matches/metallic obstructions close to antenna locations then also range can come down. Same is the case with receiving end, where the propagation effects also play a part. Keeping these two user requirements of voice and data communication in fixed-frequency mode of transmission as prime objective, the electromagnetic compatibility (EMC) solution of this new product was attempted.

2. EMI ENVIRONMENT

The EMI environment of this particular vehicle is somewhat complicated due to introduction of three radio sets in a tactical combat vehicle, out of which the HF radio set is the potential emitter of 100 W of RF power in the frequency region of 1.6 MHz to 30 MHz [AM] while the other two radio sets operate in the VHF frequency region 30 MHz to 88 MHz [FM] with an RF power output of transmitters 50 W each. Apart from these two VHF radios, there are at least four powerful electronic sub-systems which have potential EMI emission spectrum in both HF and VHF spectrum but these were tackled efficiently with EMI hardening independently and collectively (particularly in powerline EMI filtering), and hence will not be discussed in detail further. Also magnetic and electric field emissions from large current dc power generating devices are well contained by good inbuilt filtering in the source. Without this filtering, the radiated field emissions are high. Further a solid isolation/shielding is provided by partition between driver's compartment and engine compartment and hence low impedance magnetic field effects are not considered here. The EMC of communication system calls for extensive analysis with respect to transmitters, receivers, antennas and associated interconnections**.**

A term vehicle penetration loss (VPL) or the normal shielding effectiveness[3] of armoured skin of vehicular platform is very important parameter, which is expressed in decibels, is defined as the ratio of received power P_{out} immediately outside the vehicle to the received power P_{in} inside the vehicle.

$$VPL = 10\log\frac{p_{out}}{p_{in}} \qquad (3)$$

Unless the entire vehicle EM wave penetration points such as service outlets, exhaust, antenna mount seal, grills in engine compartment, weapon system mounting interfaces, etc. are treated fully for EMI seal, even the closing of crew hatches can lead to only 0 dB of VPL in spite of large thickness of usual armour skin. However, such treatment will reduce the direct field coupling from HF antenna to inside electronic equipment, which is most desirable and hence lowest EMI ambient inside the vehicle is not only to the carrier level so also to its harmonic levels.[4] It may be a worthy exercise to carry out a separate study to minimise the vehicle EM ambient by performing such treatments to various vulnerable points of EM wave penetration in large structure like a combat vehicle turret and hull. In the present study, the ambient due to four non communication electronic subsystems and all three radio sets of the communication system only are considered. Field plotting is done only for the emission from radio sets.

3. CRITERIA FOR SELECTION OF OPTIMUM LOCATION

Selecting the optimum location for the HF radio set and its accessories are basically driven by the following technical requirements:

- Least susceptible to EM ambient in its receive mode and also least EM leakages, when the transmitter is radiating its full RF power for its intended communication. That is total EMC.
- All its control knobs, displays, and settings are easily accessible to crew.
- Minimum distance prescribed by manufacturer of radio set is maintained between antenna and its coupler.
- Minimum simple hardware is required to install the system with due care for effective grounding, achieve protection against vehicle vibrations, and make effective interface to power supply, RF, control and associated connections.
- Maximum physical isolation of HF antenna to rest of coupling devices, as power involved is very high.

Once the optimum location is identified based on the above parameters, then the complete HF radio set and its accessories like antenna coupler, RF feed coaxial cable, coupler to antenna lead, power supply interface, and control interface are firmly installed in the vehicle and an *in-situ* VSWR measurement is taken to ensure the system is free from interfering sources and EM sensitive devices are physically away from the transmitter circuits.

4. CONFIGURATIONS OF COMMUNICATION SYSTEM

To finalise the configurations of communication system installation, four options of layout studies were carried out. Best advantages and least tolerable disadvantage of selecting the fourth option as final configuration from EMC point of view and other operational point of view over other options are as follows:

4.1 Option I

- **Advantages**: Minimum distance from antenna to its coupler is maintained for reducing internal radiations. Also EM radiations from coupler [both feed line and casing/housing] are contained within a closed environment.
- **Disadvantages:** The HF radio set is installed over a rotating platform. Also the accessibility to its controls is difficult. The communication system configuration of option I is shown in Fig. 3.

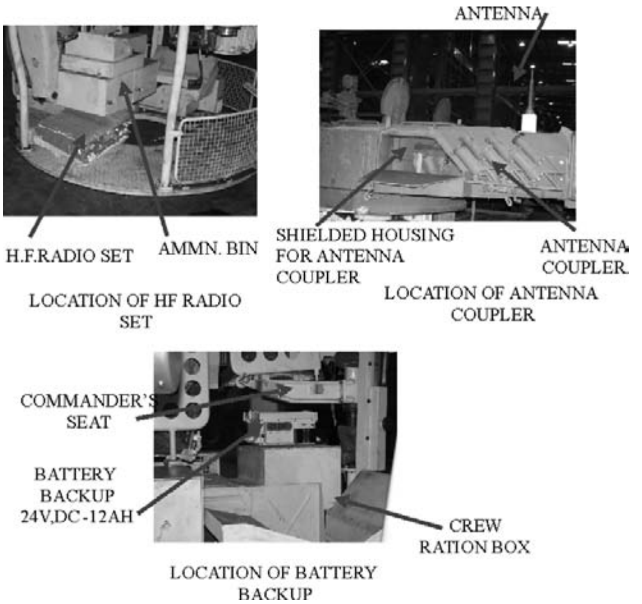


Figure 3. Commnunication system layout configuration–Option I.

4.2 Option II

- **Advantages:** The HF equipment is conveniently placed and accessible from operation point of view. It is also physically well isolated from VHF equipments and hence, better EMC situation with respect to intrasystem communication EMI threat. As required, the minimum distance from antenna to its coupler is maintained. Here also, the antenna coupler radiations are contained within close environment.
- **Disadvantages:** The HF equipment is surrounded by a number of noncommunication electronic subsystems and hence it is closer to dense EM environment. Also, its compatibility wrt collocation may definitely pose a problem. This communication system configuration of option II is shown in Fig. 4.

4.3 Option III

- **Advantages:** The advantages are same as option II. Here, the backup battery location to provide the stabilised power to communication system is different from that of option II which is a disadvantage.
- **Disadvantages:** Apart from the disadvantages of option II, there is another disadvantage i.e., the battery backup location calls for extension of cable routing that could pose some dc drop problem. This revised communication system configuration of option III is shown in Fig. 5.

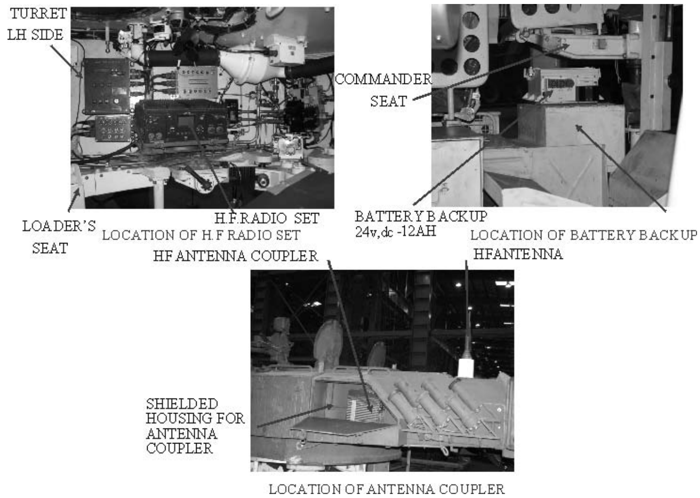


Figure 4. Commnunication system layout configuration–Option II.

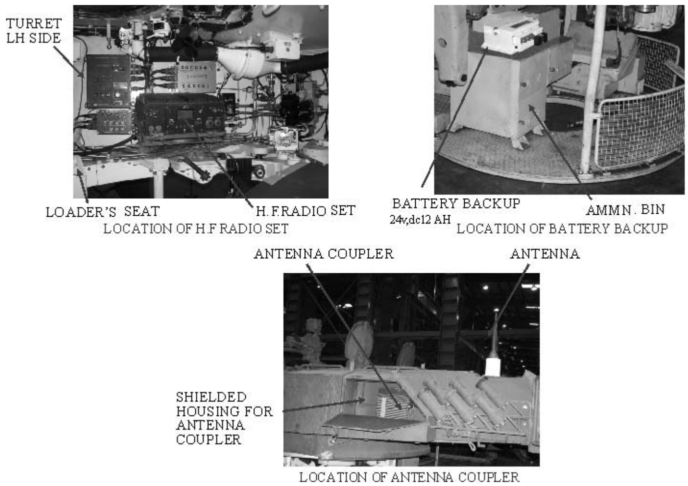


Figure 5. Communication system layout configuration–Option III

4.4 Option IV

- **Advantages:** A better access to the HF radio set, by the operator, is fully ensured. All electrical hardware of HF radio is confined to an exclusive small compartment. HF radio is totally isolated from VHF transmitters/receivers and also other electronic sub-systems, and hence, much better EMC situation is realised. As usual the minimum distance between antenna and its coupler is still maintained. Battery backup is also located closer to radio so that dc drop is not an issue unlike option III.
- **Disadvantages:** To ensure full protection to HF radio and its antenna coupler, a separate metallic partition is designed and implemented, because it should not mechanically and electrically disturb the fire control weapon stacking. The methodology adapted in this option is well accepted, but with an additional cost.

This further revised final communication system configuration of option IV which is considered as the best option from all angles in particular EMC angle is shown in Fig. 6.

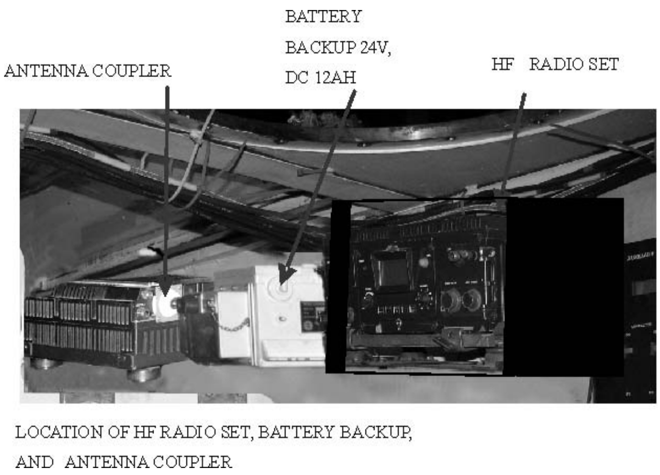


Figure 6. Communication system layout configuration–Option IV.

5. RF FIELD MAPPING EXPERIMENT

This experiment was carried out with an objective to know the RMS field strength emitted by the HF radio set under RF carrier power levels, viz. low, medium, and high selection of the set for the frequency range from 5 MHz to 30 MHz. This enables to roughly rearrange the emitter–receptor pairs of the vehicle in proper locations, so that total EMC is achieved. Depending upon the absolute value of field strength observed for the entire operating frequency range using the EMC test antenna, as called for in the MIL-STD461C/MIL-STD 464A requirements of measurements, the decision to rearrange the equipment was taken. (Measurement data collected in both vertical and horizontal polarisation enabled to understand the orientation effects of enclosures and cable coupling as the cables are run in both the directions inside the tank). Schematic of the test instrumentation used for the field probing inside the vehicle is shown in Fig. 7.

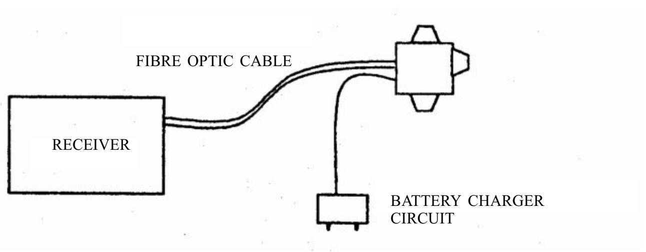


Figure 7. Test instrumentation for field monitoring.

6. HF AMBIENT PROFILE

The EM field inside the vehicle comprises radiated EM field contributed predominantly by the four non communication electronics sub-systems and three communication sub-systems, out of which the HF radio significantly radiates at high RF power, besides power supply disturbances in the form of conducted EMI. But this is of less magnitude because there is an effective powerline EMI filter at entry point of power to communication system. Also all radio sets contain a built in EMI filter that makes the magnitude of conducted EMI less. Referring to the Fig. 8, the major contribution in the frequency region of 1-30 MHz comes from HF radio set. (Also there are contributions from other equipment of the vehicle in this frequency range, but not shown here).

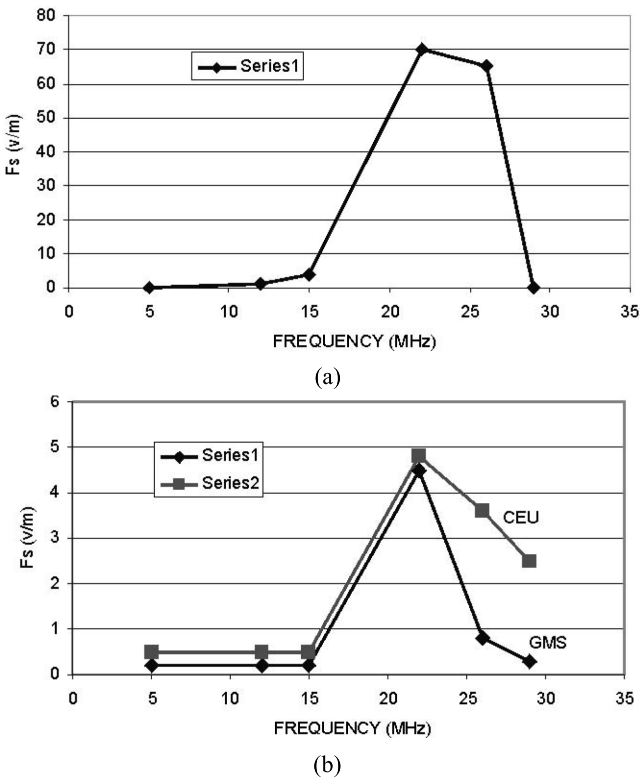
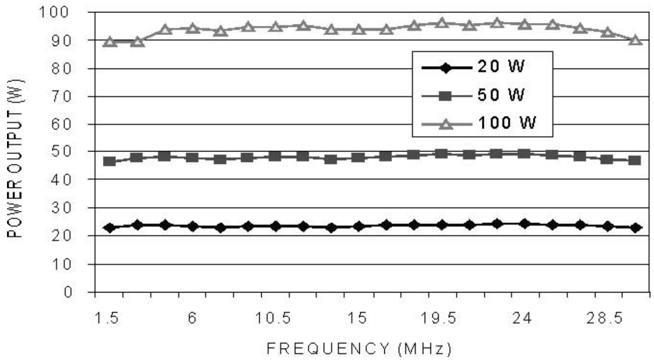


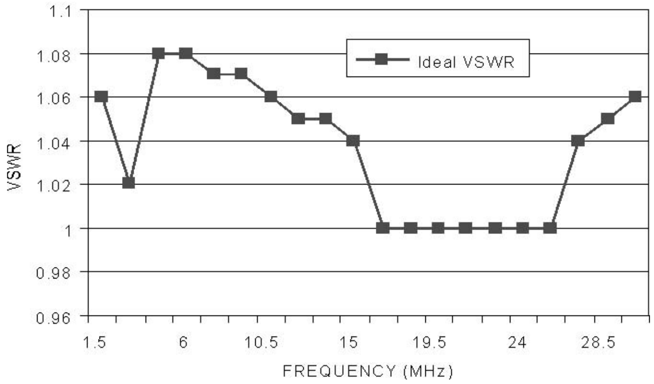
Figure 8. Measured RMS field profile of the vehicle (inside): (a) VHF radio set 1 and (b) CEU and GMS.

The voltage standing wave ratio (VSWR) is an important measurement to ensure perfect matching of antenna with radio set for effective intended radiation. Mis-matches/metallic obstructions close to antenna locations contribute to reflections and pulse broadening of carrier frequencies that can radiate in near-field zone at appreciable magnitude. This, in turn, reduces the radiated power accounting for reduction in range and also the broadening of RF carrier can be a threat to nearby electronic sub-systems onboard turret, like, the gunners main sight, electronics/commanders panoramic sight electronics, etc. The VSWR measurement was carried out in the test bench as the first step (prior to integration) followed by the same measurement *in situ* in the vehicle (after integration) to ensure that the best match is ensured and ideal location of HF antenna coupler and antenna was verified by case/cable radiations of coupler and radiation pattern of antenna.

Referring to Fig. 9, one can say that the bench level VSWR has ensured the HF radio is well matched and *in situ* measurement data reveals (not shown here but complying



(a)



(b)

Figure 9. (a) RF power output of HF radio set and (b) ideal VSWR plots at bench.

with specification value of 1.5) that there is still a slight mis-match that attributes for the reflections of nearby metallic objects. But it is fairly free from heavy reflections, for three antennas onboard turret.

Because of three radio sets operating simultaneously, intermodulation EMI frequencies (IMI) are generated by different carrier frequencies and their harmonics[5]. This also contributes for the increase in EMI ambient rise in VHF-UHF region that has an impact on other non-communication electronic sub-systems. As a whole, unless every radio set's harmonics, spurious, and emissions from other electronic sub-systems are controlled with appropriate EMI hardening measures, the ambient will continue to be more than permissible.

7. CONCLUSIONS

This study was carried out for the first time in a combat vehicle to prove that locating the high power emitter in dense EMI environment by scientific means provides better performance than attempting by trial and error means employed hitherto. Final implementation of EMC-complied communication system in the vehicle was carried out systematically, establishing a clear procedure for the user to follow considering avoiding potential EMI pick up by communication receivers. This document has come in handy for the production and inspection engineers to plan the system integration without any ambiguity. The performance of HF radio system is thus established with minimum EMI effects.

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